Application of the OSL technique for determination of the useful calibration distance ranges for beta radiation detectors

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Abstract. When beta-gamma radiation detectors are calibrated, they are initially exposed to standard gamma beams and then to standard beta beams at the calibration distances of these sources (provided in their calibration certificates). However, not always are the recommended calibration distances the ideal ones for all detectors. In this work, the useful distance ranges of the beta radiation sources were determined in order to allow the calibration of different kinds of instruments, using the optically stimulated luminescence technique. Single nanoDot detectors of Al_2O_3:C, Landauer, were utilized and characterized in standard beams of beta radiation through tests (reproducibility, linearity of response and energy dependence). Measurements were taken varying the source-detector distance mainly in small distances around the calibration distances, using ^{90}Sr+^{90}Y radiation sources. The useful source-detector distance ranges were determined for the calibration of radiation detectors.

Keywords: Beta radiation sources, calibration, optically stimulated luminescence, radiation detectors.

1. Introduction

In the calibration procedures of dose rate monitors, used in radiation protection for area monitoring, it is usual to calibrate the monitors in relation to radioprotection quantities. These instruments have to be calibrated to verify their behavior when exposed to standard radiation beams, and then they will be used in the workplaces [1,2].

In the case of beta-gamma radiation detectors, they have to be initially calibrated in standard gamma beams and then they have to be tested in standard beta radiation beams at the specific conditions provided in their calibration certificates, including reference distances and utilization of field flattening filters. However, there are several kinds of monitors that can not be calibrated at these reference distances, because they are not adequate in relation to the monitor scales.

Different radiation detectors can be calibrated at the Calibration Laboratory (LCI) at Instituto de Pesquisas Energéticas e Nucleares (IPEN) with X, alpha, beta and gamma radiations and, in the case of beta-gamma radiation monitors, the LCI use two beta secondary standard systems, with ^{90}Sr^{90}Y, ^{204}Tl, ^{147}Pm and ^{85}Kr sources [3].

Optically stimulated luminescence (OSL) is a luminescent technique already studied by several authors for different applications in dosimetry: for example, environmental, medical, dating, spatial and individual cases [4-6]. For this reason, this technique has received great interest over the time,

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and intensive research. The main material used in OSL is Al_2O_3:C, because it has showed effectiveness in all applications in which it was tested [4-7]. Some studies, as those realized by Akselrod et. al. [8] and Pinto et. al. [9], showed the behavior of the Al_2O_3:C in beta radiation beams. They reported good performance of OSL commercial detectors when exposed to this kind of radiation, but always emphasizing the high energy dependence of this material to beta radiation.

The objective of this work was to determine the useful source-detector ranges for the calibration of radiation detectors, presenting importance for the calibration laboratory, because several different kinds of beta-gamma radiation detectors are received for calibration every year.

2. Materials and Methods

NanoDot detectors of Al_2O_3:C and a microStar OSL portable reader, both from Landauer, were utilized in this work. After the steps of irradiation and evaluation, the detectors were optically treated at $26x10^3$ lux during a time interval of 24h, for reutilization.

The OSL measurements were taken after each irradiation of the detectors. For the irradiation procedure, the nanoDot detectors were positioned on a polymethymethacrylate (PMMA) support with dimensions of 120 mm x 120 mm x 15 mm, specially developed for irradiation of the dosimeters. This experimental set-up can be observed in Fig. 1, where the Al_2O_3:C detectors may be seen outside of their adapters.

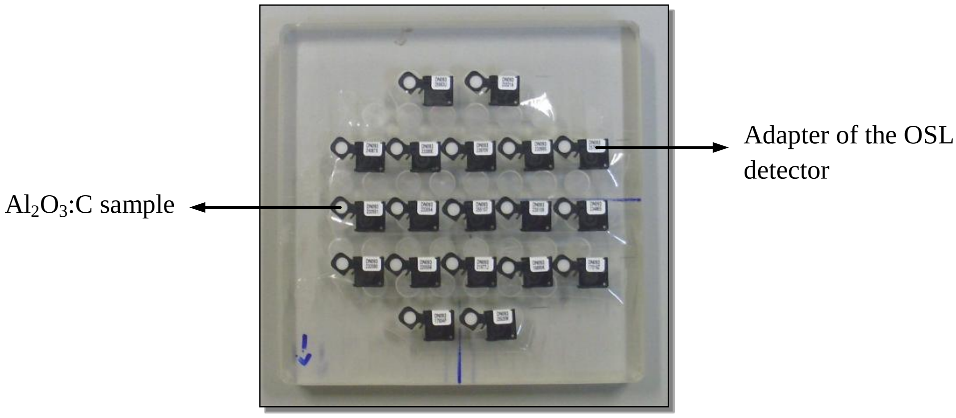

Figure 1 – NanoDot detectors of Al_2O_3:C ready to be irradiated.

During the characterization tests of the OSL response, the detectors were exposed to some sources of the two beta secondary standard systems of the LCI: BSS1, Buchler GmbH, Germany ($^{90}Sr+^{90}Y$, ^{204}Tl and ^{147}Pm), and BSS2, Isotrak, Germany ($^{90}Sr+^{90}Y$, ^{85}Kr and ^{147}Pm), that were calibrated at the primary standard laboratory, Physikalisch-Technische Bundesanstalt (PTB), Germany. The characteristics of the beta sources used in this work can be seen in Table 1.

Table 1 – Characteristics of the beta radiation sources and the conditions used in this work.

Beta Secondary Standard System	Radiation Source	Filter	Absorbed Dose Rate (µGy/s)	Nominal Activity (MBq)	Calibration Distance (cm)	Reference Date
BSS1	$^{90}Sr+^{90}Y$	No	518.4 ± 5.180	1850	11	04.02.1981
BSS2	$^{90}Sr+^{90}Y$	No	16.46 ± 0.220	460	30	12.01.2005
	^{147}Pm	Yes	2.350 ± 0.050	3700	20	19.11.2004
	^{85}Kr	Yes	39.70 ± 0.500	3700	30	30.11.2004

3. Results

The main characterization tests of the OSL response of the nanoDot detectors were reproducibility, dose-response curve, energy dependence and variation of the source-detector distance.

3.1. Reproducibility

For the reproducibility study of the OSL response of the nanoDot detectors, the $^{90}Sr+^{90}Y$ beta radiation source, of BSS2 system, was utilized. For this test, five series of irradiated, measurement and optical treatment were performed. During this study, 38 detectors were irradiated with a dose of 10 mGy. The reproducibility of the OSL response was 3.6%. After this result, a selection of the samples with similar response was made, for the subsequent studies.

3.2. Dose-Response Curve

A dose-response curve was obtained to verify the linearity of the OSL response of the nanoDot detectors of Al_2O_3:C. This study was performed irradiating the detectors with seven different doses in an interval from 1 mGy to 1 Gy, using the $^{90}Sr+^{90}Y$ source of the BSS1 system, and a source-detector distance of 11 cm. The results obtained can be seen in Fig. 2, and they are in agreement to those reported by Pinto et. al. [7], because they present linear behavior in the whole dose interval studied, from 0.5 mGy to 2 Gy. The maximum standard deviation obtained in all measurements of this study was 6.9%.

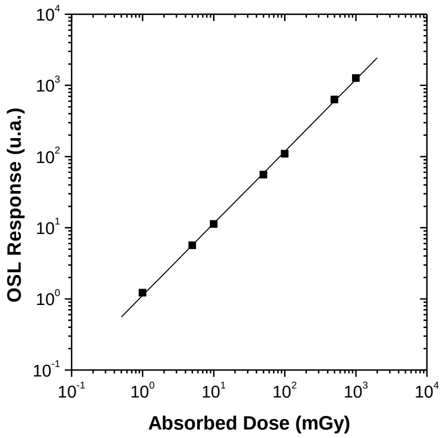

Figure 2 – Dose-response curve of OSL Al_2O_3:C detectors exposed to ^{90}Sr+^{90}Y beta standard radiation.

3.3. Energy Dependence Study

The dependence of the OSL signal with the beta radiation energy was studied using the three sources of the BSS2 system, at the conditions detailed in Table 1. The detectors were irradiated with doses of 10 mGy (^{90}Sr+^{90}Y), 10 mGy (^{85}Kr), and 165 mGy (^{147}Pm). The results obtained (Table 2) clearly revealed the high energy dependence of the OSL response of the detectors comparing the OSL response obtained between ^{90}Sr+^{90}Y and ^{147}Pm sources, and 51% in the case of the ^{90}Sr+^{90}Y and ^{85}Kr sources. The maximum standard deviation obtained in all measurements of this study was 4.4%.

Table 2 – Energy dependence of OSL response of Al_2O_3:C nanoDot detectors when exposed to beta radiation.

Source	**Beta Mean Energy (MeV)**	**OSL Response/ Absorbed Dose**
^{90}Sr+^{90}Y	0.80	1.0213 ± 0.0214
^{85}Kr	0.14	0.4965 ± 0.0110
^{147}Pm	0.06	0.0029 ± 0.0001

3.4. Variation of the OSL response in relation to the source-detector distance

The behavior of the OSL response was verified in relation to the variation between the ^{90}Sr+^{90}Y source (BSS1) and the OSL detectors. This study was performed positioning the OSL detectors at close distances of the calibration distances provided in their calibration certificates (11, 30 and 50 cm). The distances were from 10 cm to 55 cm. In Fig. 3 the results obtained in this experiment can be seen as the source-detector distance was varied. The maximum standard deviation obtained in all measurements of this study was 5.2%.

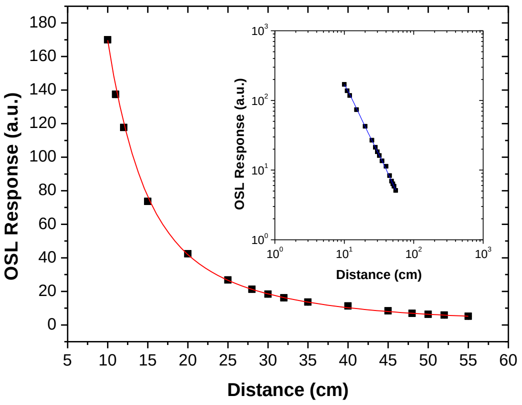

Figure 3 – Variation of the ionization chamber response in relation to the distance between the OSL detectors and the $^{90}Sr+^{90}Y$ source (BSS1, 1850 MBq, 1981).

The results obtained in the measurements and the curve (Fig. 3) show that the OSL detector response follows the inverse square law in relation to the source-detector distance.

4. Conclusions

The results obtained during the development of this work, in relation to the reproducibility and linearity of the OSL response, showed the efficiency of the nanoDot detectors in standard beta radiation fields. The energy dependence test revealed the strong dependence of the nanoDot OSL response with the energy of the beta sources used ($^{90}Sr+^{90}Y$, ^{85}Kr and ^{147}Pm).

The main study of this work, essential for the accomplishment of its main objective, was the verification of the nanoDot response in relation to the variation of the source-detector distance using the $^{90}Sr+^{90}Y$ source (between 10 cm and 55 cm). The results obtained in this experiment showed that the OSL response follows the inverse square law.

The conclusions are of relevant importance for the Calibration Laboratory, because the calibration of several different models and kinds of monitors, mainly with different scales, will be possible by the determination of the absorbed dose rates at any distance among those tested.

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